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**TECHNICAL MANUSCRIPT 505**

**REQUIREMENTS OF CULTURED  
MAMMALIAN CELLS  
FOR VITAMIN B 12 AND BIOTIN**

Kiyoshi Higuchi

MAY 19 1969

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**DEPARTMENT OF THE ARMY  
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TECHNICAL MANUSCRIPT 505

REQUIREMENTS OF CULTURED MAMMALIAN CELLS FOR  
VITAMIN B<sub>12</sub> AND BIOTIN

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Medical Bacteriology Division  
BIOLOGICAL SCIENCES LABORATORIES

Project 1B562602A082

April 1969

ABSTRACT

Eagle reported in 1955 and 1957 that eight vitamins were essential for the growth of most mammalian cells in culture. No evidence for requirement of vitamin B<sub>12</sub> or of biotin was presented. Sanford and co-workers in 1963 and 1964 reported evidence for requirement of both of these vitamins in certain cell strains, but no quantitative data were presented. In 1967, Ham reported that  $3 \times 10^{-10}$  M biotin permitted successful cloning of a Chinese hamster cell line. We have found that both HeLa and L cells required approximately  $10^{-11}$  to  $10^{-10}$  M vitamin B<sub>12</sub> for optimal growth in a chemically defined medium. Requirement of HeLa cells for biotin was demonstrated initially with avidin, a biotin inactivator. The inhibitory activity of avidin on growth of HeLa cells was reversible by addition of biotin. Serial passage of both HeLa and L cells in presumably biotin-free medium resulted in achieving biotin-deficient cells. Both cell lines required approximately  $10^{-8}$  M biotin for optimal growth in a chemically defined growth medium.

### I. INTRODUCTION\*

The minimum vitamin requirements of HeLa and L cells in tissue culture were reported by Eagle<sup>1</sup> in 1955 to be choline, folic acid, nicotinamide, pantothenate, pyridoxal, riboflavin, and thiamine. He pointed out that additional essential factors might be identified when better media and techniques became available. Eagle used a medium containing dialyzed serum in his studies. In 1957, he and others reported that myo-inositol was also essential for growth of most cell lines.<sup>2</sup> In 1963, Sanford and co-workers, using chemically defined culture media, described experiments in which an apparent variant of the mouse fibroblast, strain L, was isolated that required vitamin B<sub>12</sub> for optimal rate of growth.<sup>3</sup> The parental L cells showed no clear-cut response to vitamin B<sub>12</sub>. In a later publication, Sanford and Dupree<sup>4</sup> reported that nine other cell strains of various species of origin (including strain HeLa) grew in the absence of vitamin B<sub>12</sub> for prolonged periods with no evidence of deficiency.

Biotin is another substance that has been studied extensively in efforts to demonstrate requirement for it by animal cells in vitro. Sanford, Dupree, and Covalesky<sup>5</sup> in 1963 described work in which evidence for biotin deficiency in a clonal line of strain L was observed in long term experiments. More recently, Ham<sup>6</sup> reported that successful cloning of a Chinese hamster cell line occurred in a chemically defined medium only if supplemented with  $3 \times 10^{-10}$  M biotin.

It seemed desirable, in view of the limited knowledge of the role of these two vitamins in animal cells in vitro, that further work be undertaken in this area. The work presented here shows that vitamin B<sub>12</sub> and biotin are required by both HeLa and L cells.

### II. MATERIALS AND METHODS

The chemically defined medium used for cultivation of HeLa and L cells is described in Table 1. The composition of the medium is, with certain exceptions, essentially similar to that of many described by others. Details on the development of the medium are not covered here. This medium permitted unlimited serial propagation of HeLa and L cells in a chemically defined nutritional environment.

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TABLE I. COMPOSITION OF THE CHEMICALLY DEFINED GROWTH MEDIUM

L Amino Acids:	mg/Liter	Vitamins:	mg/Liter
arginine·HCl	32	D-biotin	1.0
asparagine·H <sub>2</sub> O	150	choline·Cl	1.0
cysteine HCl·H <sub>2</sub> O	22	D-Ca-pantothenate	2.0
glutamine	196	folic acid	1.0
histidine HCl·H <sub>2</sub> O	63	inositol	1.0
isoleucine	33	niacinamide	1.0
leucine	26	pyridoxal·HCl	1.0
lysine·HCl	28	riboflavine	0.1
methionine	15	thiamine·HCl	1.0
phenylalanine	33	vitamin B <sub>12</sub>	0.002
proline	115	<u>Inorganic Salts:</u>	
serine	105	NaCl	7,400
threonine	12	KCl	400
tryptophan	6.3	NaH <sub>2</sub> PO <sub>4</sub> ·H <sub>2</sub> O	200
tyrosine	46	NaHCO <sub>3</sub>	720
valine	35	CaCl <sub>2</sub> ·2H <sub>2</sub> O	265
<u>Miscellaneous:</u>		MgCl <sub>2</sub> ·6H <sub>2</sub> O	275
glucose	1,800	Fe(NH <sub>4</sub> )(SO <sub>4</sub> ) <sub>2</sub>	4.8
Na gluconate	218		
Na pyruvate	110		
methylcellulose (15 cps)	500		
phenol red	10		
insulin	(0.05 U/ml)		

Tests for Mycoplasma contamination made at intervals showed no extraneous organism in either culture.

Plastic Falcon T-30 culture flasks containing 5 ml of culture medium were employed exclusively.

Cell growth response was assayed by measuring increased cellular protein in the cultures by the procedure of Oyama and Eagle.<sup>6</sup>

### III. RESULTS AND DISCUSSION

#### A. VITAMIN B<sub>12</sub>

The data in Figure 1 show the growth response of HeLa cells to vitamin B<sub>12</sub> in the chemically defined medium. Data from duplicate cultures are presented. Cells used as inoculum were grown through six cell-doublings in medium free of vitamin B<sub>12</sub> prior to use in the experiment. Approximately 22,000 cells/ml were inoculated. The cultures were fed three times during the 8-day incubation period before cells were harvested for cell protein assay. In this test less than 10 picograms/ml of vitamin B<sub>12</sub> (about 10<sup>-11</sup> M) were adequate to yield peak growth. The results indicate that vitamin B<sub>12</sub> is essential for growth of HeLa cells.

It must be remembered that because of possible trace contamination of reagents with vitamin B<sub>12</sub> and, probably more significantly, because of the substantial number of cells required as inoculum for initiation of cell multiplication regardless of vitamin B<sub>12</sub> concentration, the so-called zero level of the vitamin in these experiments is only an approximation.

In similar experiments with L cells, growth responses were less clear-cut. Data from one experiment are shown in Figure 2. The cells used as inoculum were grown through at least 20 cell-doublings in medium free of vitamin B<sub>12</sub> prior to use in the experiment. The cultures were fed twice during the 8-day incubation period. Approximately 30,000 cells/ml were used as inoculum. The concentration range for producing growth response in L cells was approximately the same as for HeLa cells; however, the data indicate that the L cell may need higher concentrations of vitamin B<sub>12</sub> than the HeLa cell.

The ability of deoxynucleosides to substitute for vitamin B<sub>12</sub> in the nutrition of certain microorganisms is well known. In the case of HeLa cells, thymidine in a wide range of concentrations failed to show any vitamin B<sub>12</sub> - sparing effect. Data are shown in Table 12. It appears, therefore, that the response of HeLa cells to vitamin B<sub>12</sub> is very much like that of the flagellate Ochromonas malhamensis, an organism commonly used in the bioassay of vitamin B<sub>12</sub>. On the other hand, Sanford and Dupree also had reported that their cell strain 3654 required vitamin B<sub>12</sub> even in the presence of certain nucleic acid derivatives.<sup>4</sup>

#### B. BIOTIN

The data in Table 3 show that a requirement for biotin was demonstrable when avidin was added to the growth medium. The activity of this specific inactivator of biotin was apparently reversible by biotin. The HeLa cells used in this experiment were grown twice in "biotin-free" medium but showed no evidence of biotin deficiency unless treated with avidin.

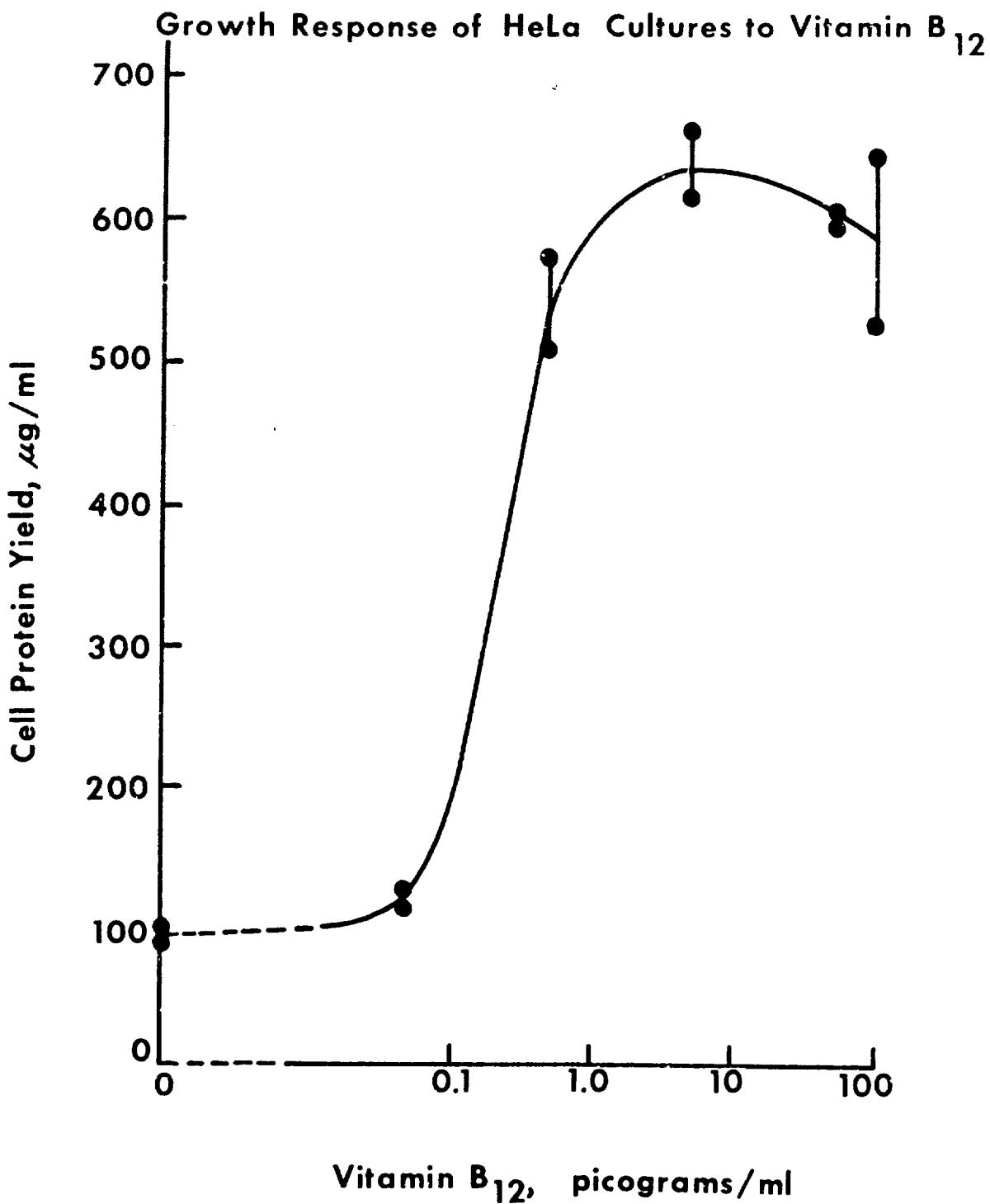


FIGURE 1. Growth Response of HeLa Cultures to Vitamin B<sub>12</sub>. The graph was drawn as a smooth curve through points representing averages of duplicate values. The breaks in the curve in the region approaching zero concentration of the vitamin are required in order to avoid misrepresenting the scale and yet to present the zero point.

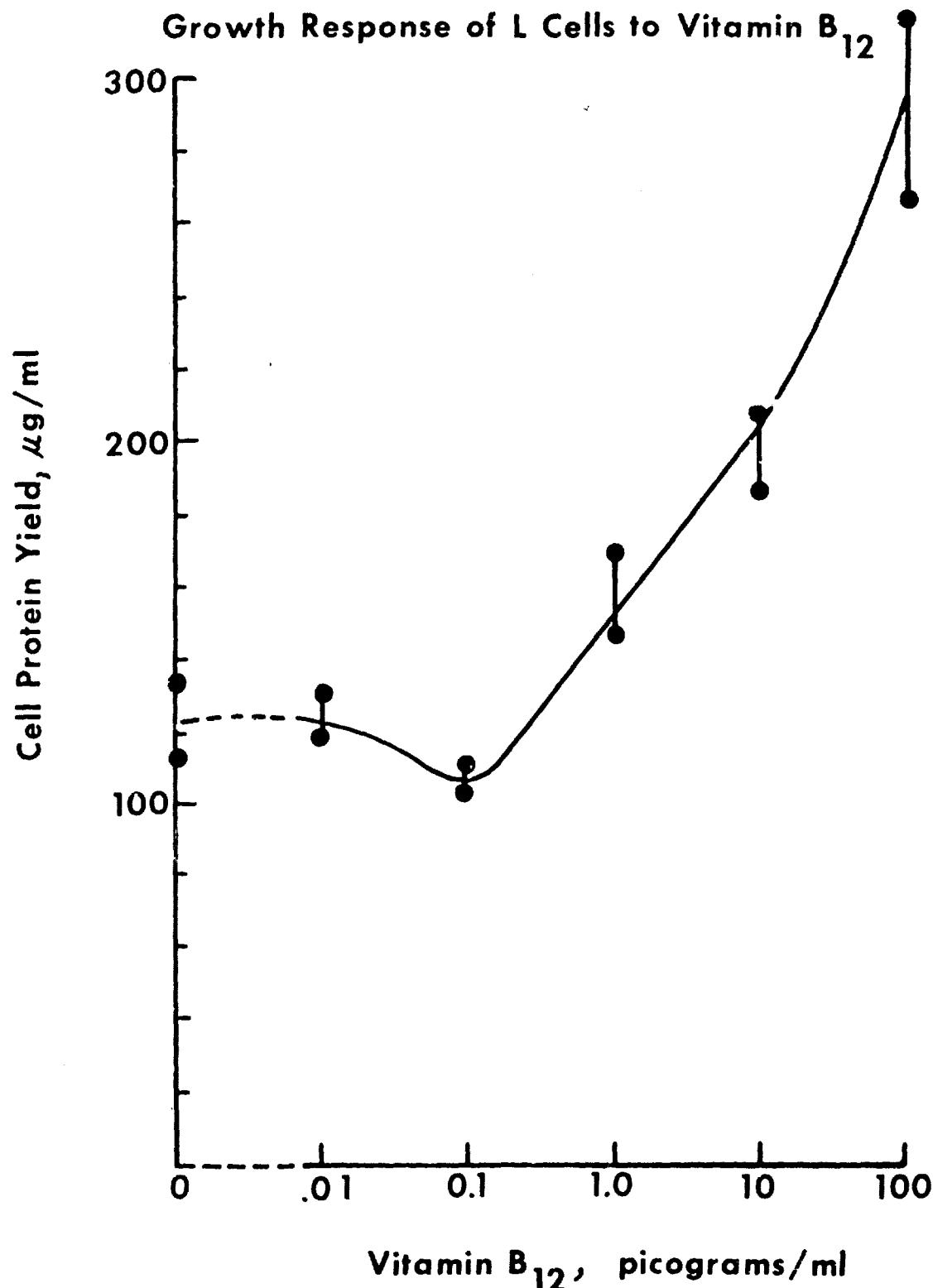


FIGURE 2. Growth Response of L Cells to Vitamin B<sub>12</sub>. The graph was drawn as a smooth curve through points representing averages of duplicate values. The breaks in the curve in the region approaching zero concentration of the vitamin are required in order to avoid misrepresenting the scale and yet to present the zero point.

TABLE 2. FAILURE OF THYMIDINE TO SUBSTITUTE FOR VITAMIN B<sub>12</sub> IN HeLa CELLS

Growth Conditions	Cell Protein Yield, $\mu\text{g}/\text{ml}^{\text{a}}$
Control (no B <sub>12</sub> , no thymidine)	86, 76
Control with 50 picograms/ml B <sub>12</sub>	383, 375
Control with 10 <sup>-6</sup> M thymidine	88, 74
Control with 10 <sup>-5</sup> M thymidine	54, 50
Control with 10 <sup>-4</sup> M thymidine	32, 28

a. Values from duplicate cultures are presented.

TABLE 3. INHIBITORY EFFECT OF AVIDIN ON GROWTH OF HeLa CELLS AND ITS REVERSAL BY BIOTIN

Avidin, $\mu\text{g}/\text{ml}$	Biotin, $\mu\text{g}/\text{ml}$	Cell Protein Yield, $\mu\text{g}/\text{ml}^{\text{a}}$
0	0	250, 245
4.4	0	17, 12
22	0	16, 15
0	0.02	205, 200
22	0.02	210, 225

a. Values from duplicate cultures are presented.

Because unequivocal evidence was obtained that biotin was needed for growth, it may be assumed that previous failures were due either to incomplete depletion of the vitamin in the inoculum or to trace contamination of the basal medium with biotin. Subsequently, after seven repeated passages of HeLa in presumably biotin-free medium, the data shown in Figure 3 were obtained. It appears that approximately 10<sup>-8</sup> M biotin (2.44 nanograms/ml) is required for optimal growth of HeLa cells in the defined medium. Similarly, L cells were serially passed in the biotin-deficient medium four times and tested for response to biotin (Fig. 4). The results obtained with these two cell lines indicate that a requirement for biotin may be a characteristic of many or all cultured mammalian cells.

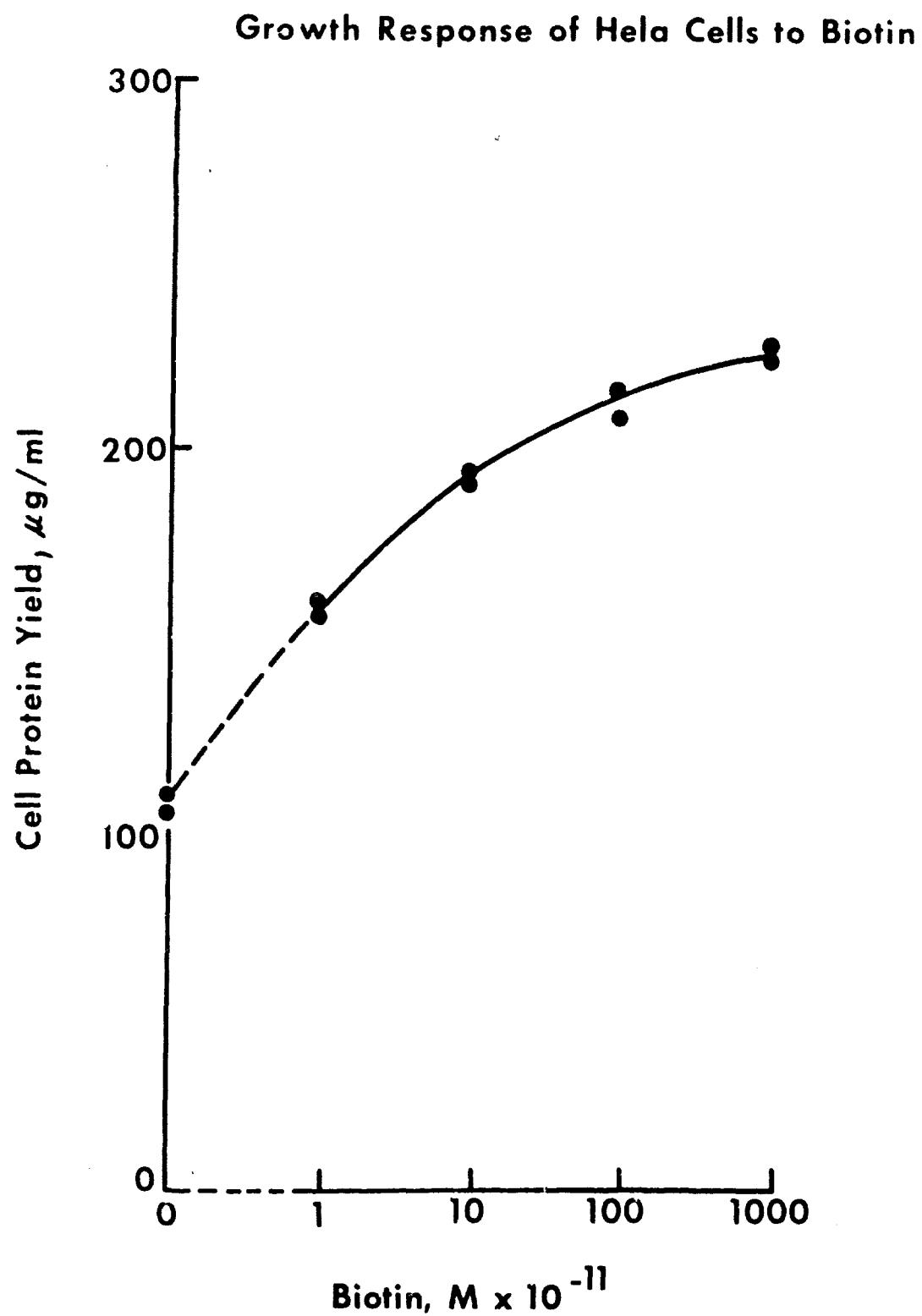


FIGURE 3. Growth Response of HeLa Cells to Biotin. The graph was drawn as a smooth curve through points representing averages of duplicate values. The breaks in the curve in the region approaching zero concentration of the vitamin are required in order to avoid misrepresenting the scale and yet to present the zero point.

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### Growth Response of L Cells to Biotin

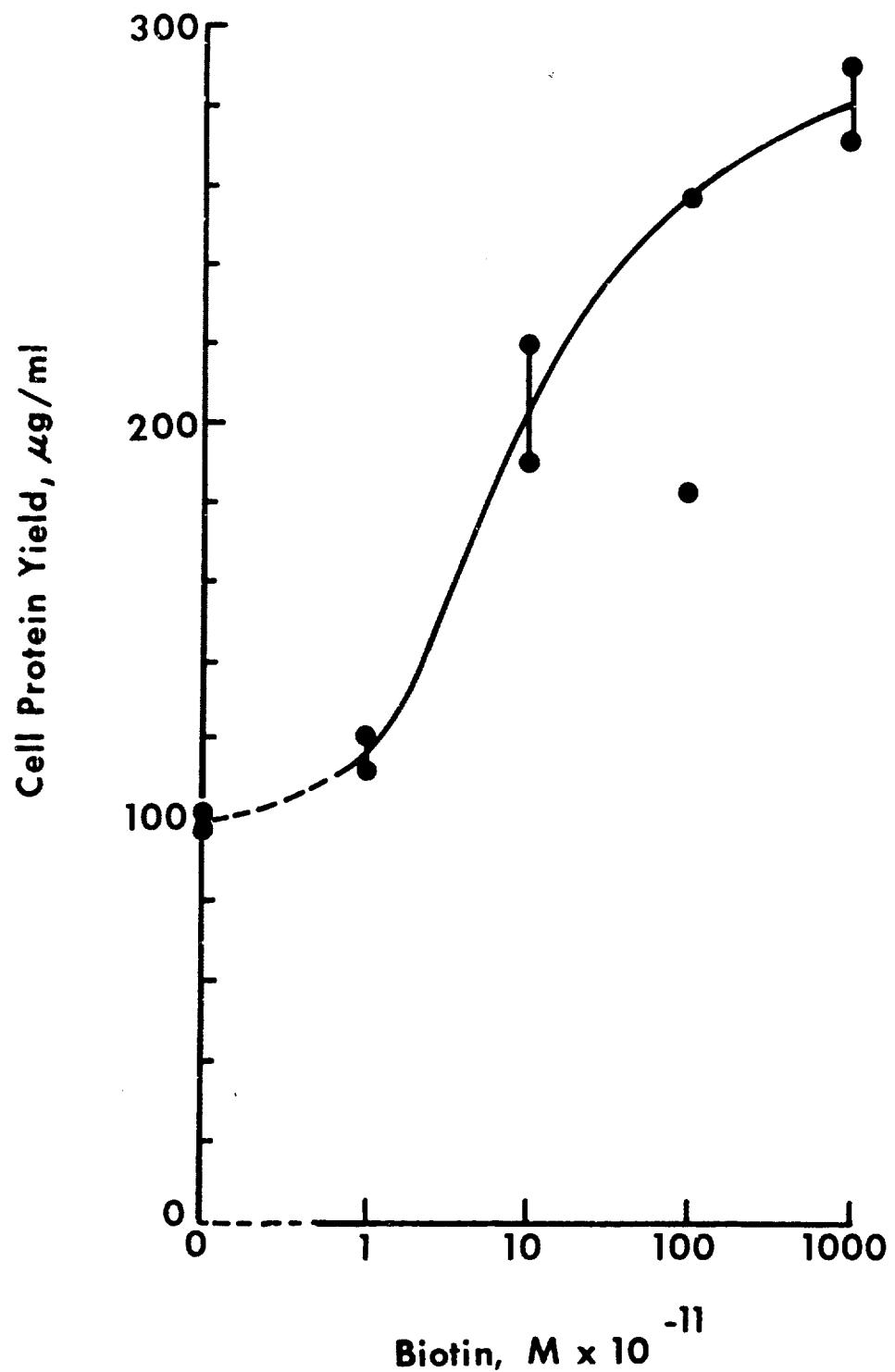


FIGURE 4. Growth Response of L Cells to Biotin. The graph was drawn as a smooth curve through points representing averages of duplicate values. The breaks in the curve in the region approaching zero concentration of the vitamin are required in order to avoid misrepresenting the scale and yet to present the zero point.

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